SEA WAVE PATTERN EVALUATION — PRESSURE DISTRIBUTIONS:

Users' Guide

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Abstract

This is the users' guide for the program `SWPE-PD` (Sea Wave Pattern Evaluation — Pressure Distributions) which determines the waves produced by a distribution of pressure applied to the air-sea interface, moving with constant velocity over an otherwise-calm sea.

1 Introduction

The purpose of the program `SWPE-PD` is to determine the waves that are produced by a user-supplied surface-pressure distribution, such as would be produced by a hovercraft for example. In brief, the user supplies the value of the pressure applied at each vertex of a rectangular grid which covers the pressure region, and the program determines the elevation of the sea's surface at each vertex on another rectangular grid covering the flow domain. Input is achieved via a single input file, within which the user may set physical parameters (such as sea depth, eddy viscosity, gravitational acceleration, fluid density and the speed at which the pressure distribution is translating), pressure-distribution parameters (such as location, length, width, resolution and applied pressure), and fluid-domain parameters (such as location, length, width and resolution). The primary output is a single file which contains the sea-surface-elevation data at each point specified in the fluid domain.

This program has been based on, developed from, and is in many ways analogous to `SWPE` (Sea Wave Pattern Evaluation) which determines the sea-surface elevations produced by a thin ship. The `SWPE` documentation may also be of use to users of `SWPE-PD`. `SWPE-PD` is an interim step in the development of `SWPE-FS` (Sea Wave Pattern Evaluation — Flat Ships) which is intended to do the same as `SWPE` but for vessels of small draft such as speedboats.

2 Operation and inputs

The source code consists of the file `swpe-pd.f` and a series of `FORTRAN` include files. `swpe-pd.f` contains a call to the `NAG` library's linear-system solver `F04ARF`. If the `NAG` library is unavailable to the user, then the code contains instructions on how to replace the call to `F04ARF` with a call to the `LAPACK` linear-system solver `DGESV`. One can obtain a copy of the public-domain licensed `LAPACK` library from the internet. An executable is produced by compiling `swpe-pd.f`, linked with the linear system solver's library, e.g.

```
> f77 swpe.f -lnag
```

Upon execution, the program takes all its input from the single file `swpe-pd.in`, an example of which is shown on page 3. The input file must be of this specific format as it contains a mix of text and data. The lines of text are discarded by the program immediately — the only thing of importance is the order in which the variables are assigned their values. The input data is tested to ensure it passes feasibility criteria in order to provide some protection against user error. For example, the value supplied for gravitational acceleration must be non-negative. If the input data fails the test, an error message will be reported and the program will abort immediately. In addition, the program reports the values it is assigning to variables (rather than merely echoing lines of input) so that the user can verify that variables are taking on their intended values. SI units are assumed throughout. The input file is separated into three logically distinct sections, dealing with physical parameters, wave calculation parameters and pressure distribution definitions respectively.

```
================================================================================
                                  swpe-pd.in
        SEA WAVE PATTERN EVALUATION - PRESSURE DISTRIBUTIONS: INPUT FILE
================================================================================
Note 1: Constant pressure distribution
Note 2: Aspect ratio = 0.5
Note 3: Infinite depth fluid
Note 4: Froude number = 1/sqrt(2)
Note 5: Zero eddy viscosity
----------------------------- PHYSICAL PARAMETERS ------------------------------
Gravitational acceleration (m/sec/sec)
1.0
Fluid density (kg/litre)
1.0
Water eddy viscosity (sq. m/sec)
0.0
Water depth (m) (min 0.0, greater than 1d100 implies infinite-depth case.)
9d100
Distribution speed (m/sec)
1.0
------------------------- WAVE CALCULATION PARAMETERS --------------------------
Field x_min (metres) (decimal)
-2.0
Field x_max (metres) (decimal >= x_min)
2.0
Number of field x-nodes (integer)
5
Field y_min (metres) (decimal)
-1.0
Field y_max (metres) (decimal >= y_min)
1.0
Number of field y-nodes (integer)
5
Height of evaluation nodes (metres) (decimal <= 0.0)
0.0
----------------------- PRESSURE DISTRIBUTION DEFINITION -----------------------
Number of distributions (integer)
1
--------------------------- PRESSURE DISTRIBUTION 1 ----------------------------
X-coordinate of centre of distribution (metres)
0.0
Y-coordinate of centre of distribution (metres)
0.0
Length of distribution (metres)
2.0
Width of distribution (metres)
1.0
Maximum pressure (Pascals)
1.0
Number of stations (integer)
3
Number of buttocks (integer)
3
Distribution pressures (Pascals) (decimals)
1.0 1.0 1.0
1.0 1.0 1.0
1.0 1.0 1.0
================================== end of file =================================
```

Physical parameters: Gravitational acceleration, fluid density and distribution speed are self-explanatory.

The program has two modes of execution that depend upon water depth. If a depth in excess of 10^{100} is supplied, then both the local and far-field are determined using their infinite-depth formulations. If a depth less than this is supplied, then the fluid is assumed to be of finite depth and the far-field is determined using its finite-depth formulation. (The near-field computation uses the infinite-depth formulation and is in this case invalid.) Thus, the user can choose between infinite and finite-depth implementations simply by supplying an appropriate value for water depth.

Water eddy viscosity is a damping factor that determines how rapidly the higher-frequency (diverging) waves are diminished in amplitude. In SWPE Part 3 Report [1], a value of the order of 0.005 was suggested. That report may be consulted for further discussion of the eddy-viscosity correction factor.

Wave calculation parameters: The input variables `field_x_min`, `field_x_max`, `field_y_min`, `field_y_max`, the number of x-nodes and y-nodes and the evaluation-node height describe the rectangular grid at whose vertices the velocity potential and its derivatives are to be determined. The pressure distribution is presumed to be stationary relative to a frame of reference that is translating in the negative-x direction, so that waves will exist only for values of x greater than the leading edge of the pressure distribution. Thus, `field_x_min` is "upstream" and `field_x_max` is "downstream". The coordinate system is right-handed, with positive x being behind the pressure distribution, positive y being starboard and positive z being vertically up.

Pressure distribution definition(s): It is possible to determine the elevations due to multiple pressure distributions. To do so, one must supply the number of pressure distributions to be implemented, and then a detailed description of each such pressure distribution.

The x-coordinate, y-coordinate, length, and beam define the location of the pressure distribution. Together with the number of stations (i.e. x-wise locations) and number of buttocks (i.e. y-wise locations) they define the rectangular grid upon which the pressure distribution is to be represented. The patch pressures are to be supplied at the intersection of each station and buttock, with the rows representing stations and the columns representing buttocks. Thus, the first entry on the second row of the pressure input data is the pressure to be applied at the first buttock (i.e. the left most edge) of the second station (as counted from the leading edge of the pressure distribution).

The pressure distribution is assumed to vary piecewise quadratically in both the x and y directions. That is, the pressure is assumed to be parabolic between the first and third stations, third and fifth stations, etc. Unlike a quadratic spline, the derivative of pressure is not assumed to be continuous at the intersection of neighbouring parabolae. The variation between buttocks is analogous. Thus, the pressure distribution must be represented by both an odd number of stations and an odd number of buttocks. For example, a constant pressure patch can be represented by a minimum of three stations and three buttocks, with all supplied pressures being equal.

Multiple pressure distributions can be implemented simply by adding additional pressure distribution definitions to the input file. In such a way, a pressure distribution of complicated plan-form or requiring regions of differing resolution can be constructed.

3 Outputs

The primary output of the program is the file `swpe-pd.out` which contains the sea-surface elevation at each point in the flow domain. Specifically, each row of data contains, in order, the x-coordinate, y-coordinate, z-disturbance, velocity potential, and the x, y and z-components of velocity. If the supplied evaluation-node height is zero, then the velocity potential and its derivatives are evaluated at the free surface, and the z-disturbance is equal to the free-surface elevation. If the evaluation-node height is negative, then the velocity potential and its derivatives are evaluated at that depth, and the z-disturbance is that which is experienced by a fluid particle that would initially have been at the evaluation-node height. Each row of field points is separated by a blank line. This format is suitable for immediate plotting using gnuplot.

In addition, the files `local_field.out` and `far_field.out` contain the same information in the same format, except that they are for the local and far-field components respectively. Note that when in finite-depth mode, of these three ouput files, only `far_field.out` is valid.

The file `pq.out` contains the values of $P(x, \theta)$ and $Q(x, \theta)$, as defined in [2] with x determined by `field_x_max`, the rear-most boundary of the computational domain. If that boundary lies beyond the rear of the pressure distribution, then these values represent the components of the far-field wave-amplitude spectrum, and can be used to evaluate the wave resistance. If valid, the wave resistance is determined and the result is displayed during program execution.

Finally, the file `offsets.dat` contains the x and y-coordinates of each vertex of the pressure-distribution grid, along with the corresponding value of the pressure supplied from the input file. Again, this file is formatted to be suitable for immediate plotting using gnuplot.

4 Internally modifiable parameters

The internal workings of the program are beyond the scope of this document. The mathematical formulation of the program is discussed in [2]. The code is sufficiently documented using comments to enable a suitably skilled individual to understand and modify its behaviour. There are however a few internal parameters that can be modified easily to alter the speed, accuracy and capacity of `SWPE-PD`.

`max_nthm1` is one less than the maximum number of intervals used in the numerical approximation to the far-field theta integration. In fact, within the code, the variable `nthm1` is set to the value of `max_nthm1` so that `max_nthm1` directly controls the actual number of intervals used in the numerical approximation to the far-field theta integration. This parameter controls the accuracy and speed of the far-field calculations. Using a larger value will result in a more accurate result, but at the expense of additional execution time.

`max_nsm1` is one less than the maximum number of stations that the pressure distribution may be represented by. Similarly, `max_nbm1` is one less than the maximum number of buttocks that may be used. Thus, one can modify the capacity of the program to handle greater/lesser body resolutions. `max_nfrm1` is one less than the maximum number of rows that the fluid domain may comprise. Similarly, `max_nfcm1` is one less than the number of columns that may be allowed. Thus, the user can modify the capacity of the program to handle a greater/lesser number of field points within the fluid domain. Note that the actual number of stations, buttocks, rows and columns used in any given execution of the program is determined by the values supplied in the input file. These parameters need only be increased if their default values are insufficient. The main consequence of using larger values for these parameters than is necessary is that the program will require more memory during execution.

All these parameters can be modified in the source file `parameters.inc`. There are no other user-modifiable parameters.

5 Accuracy of velocity components

As discussed in the accompanying document [2], without special care, the local-field computations may become less accurate as singularities are approached (i.e. near the intersection of stations and buttocks). Such care has been taken for the local-field potential, velocity components and free-surface elevations, with each being "desingularised" to the extent deemed most appropriate.

For the vertical component of the velocity, where partial-desingularisation techniques have been implemented, the z-velocity will be inaccurate at and near the leading and trailing edges of the applied pressure region, but the accuracy of the results will increase rapidly with distance or depth.

By comparison, it is imperative that the x-component of the velocity (which is closely related to the free-surface elevation) be accurate everywhere on the free-surface, including at singularities. Accordingly, full-desingularisation techniques have been implemented for that component. A side-effect is that the x-component of velocity becomes less accurate as depth is increased, with inaccuracies being restricted to the regions directly beneath the leading and trailing edges of the applied pressure region.

Both the potential and the y-component of velocity are accurate everywhere.

6 Conclusion

The program is simple to operate, taking all input from the single input file `swpe-pd.in`. The user may set physical parameters (such as sea depth, eddy viscosity, gravitational acceleration, fluid density and the speed at which the pressure distribution is translating), pressure-distribution parameters (such as location, length, width, resolution and applied pressure), and fluid-domain parameters (such as location, length, width and resolution).

max_nthm1 is the only user-modifiable parameter that can affect the speed and accuracy of the program. The four parameters max_nsm1, max_nbm1, max_nfrm1 and max_nfcm1 can be modified to change the capacity of the program to handle a greater/lesser body resolution and number of field points within the fluid domain, but changing these parameters is only necessary if their default values are insufficient.

The primary output of the program is the file swpe-pd.out which contains the sea-surface elevation and velocity at each point in the flow domain. In addition, the files local_field.out and far_field.out contain the same information for the local and far-field components respectively.

Thus, using SWPE-PD, one can easily determine the waves that are produced by a distribution of pressure applied to the air-sea interface by vessels such as hovercraft.

Users wishing to modify the behaviour of SWPE-PD will, in addition to the detailed comments embedded within SWPE-PD, need to consult the accompanying report [2] on the mathematics behind the formulation.

References

[1] Tuck, E.O., Scullen, D.C. and Lazauskas, L. *Sea Wave Pattern Evaluation, Part 3 report: Near-Field Waves*, Scullen & Tuck Pty Ltd, Adelaide, January 2000.

[2] Scullen, D.C. and Tuck, E.O. *Sea Wave Pattern Evaluation — Pressure Distributions: Mathematical formulation*, Scullen & Tuck Pty Ltd, Adelaide, July 2001.